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SOME LITTLE EMPHASIZED GUIDE-POSTS TO MEDICAL ENTOMOLOGY.*

William A. Riley.

To address the members of the Entomological Society of America on the subject of the history of medical entomology may seem a needless presumption. Immediately when the topic is mentioned there occurs the thought that medical entomology is a branch of our favorite study too young to have a history.

The discoveries of the relations of insects to disease which have revolutionized the attempts to control some of the most devastating diseases of man and animals have been made within the memory of even the younger in this audience. So spectacular have they been in some instances, and so far-reaching in their application that they have been featured by the popular magazines and by the daily press. Today it is common knowledge that many diseases, whose origin and spread were shrouded in mystery a few short years ago are insect borne.

It is often said that these discoveries have all been made within the past twenty-five years. And yet, the worker in science knows that no new discovery—no pregnant theory—originates suddenly. There is no more a spontaneous generation of important scientific theories, uninfluenced by pre-existing knowledge and thought than there is spontaneous generation of the higher forms of life.

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To trace the development of science, or some particular phase of a science is not a mere idle amusement. Regarding history Emerson has said it is "A looking both before and after as, indeed the coming Time already waits unseen, yet definitely shaped, pre-determined and inevitable, in the Time come; and only by the combination of both is the meaning of either completed." So, too, in the field of biology the discovery of today is but the fruitage of a tree rooted deep in the past. And this fruitage in turn though many of its seeds may fall by the wayside will yield the germ from which will come still better fruit.

Many workers have already called attention to early suggestions or even carefully worked out theories regarding the relation of insects to disease. In some cases these suggestions have been over-valued, through being interpreted in the light of present day knowledge. In some instances it is evident that a keen pioneer worker had grasped and all but established the truth which was first to be accepted many years later.

Yet these suggestions were largely lost sight of, and lay dormant for decades and even for centuries. Why was not this also the fate of the suggestions of twenty-five years ago? The answer lies in the history of zoology, and it is this general topic in its relation to medical entomology which I wish to touch upon tonight. This phase I have already presented in outline in an earlier discussion.

The subject is a broad one—it might well serve as the occasion for pointing out that there are no unrelated truths and that all branches of science contribute to genuine advancement in the field of human knowledge.

It is obvious that the work of Pasteur and Koch, resulting in the development of the science of bacteriology, has had a most intimate and profound influence in bringing about an understanding of the role which insects and their allies play in the transmission of disease.

However much the influence of modern bacteriology is recognized, it is not so generally known that from the time of the discovery of bacteria by the Jesuit priest, Athanasius Kircher, in 1658, and by Leeuwenhoek, there was a period of over a century when the germ theory of disease was the dominant one in medicine and most profoundly affected workers in biology. Though this influence was an intangible one, it must nevertheless be reckoned with. However important this intangible influence may have been and however fundamental bacteriology has been to the development of medical entomology, the outstanding guide-posts of a century and more ago were in the field of helminthology, or the study of the grosser parasites of man and animals.

We laugh today at the crudities of the early zoologists who taught in the most matter-of-fact manner, amazing theories of heterogenesis, according to which the offspring of a given animal may be something utterly different from itself. However deeply ingrained they were in the popular mind, theories of the development of geese from barnacles, or of the spontaneous generation of frogs from mud, of mice from grain, and of bees from dead oxen were discarded by the advanced scientists of the 17th century.

Much more slowly did this changed viewpoint apply to the various helminths or intestinal worms. We know that Redi with all of his keenness and daring was unwilling to commit himself to the view that the endo-parasites of animals might not originate spontaneously. It is more surprising to find that as late as 1819 the noted parasitologist Bremser presents a careful, and, for the period, convincing argument in favor of the spontaneous origin of these forms. The noted medical treatise by Roche and Sanson, in 1828, declares that the opposing view according to which the helminths are transmitted from animal to animal, being introduced into the body through the air, or food, or drink, demands such a measure of credulity that it is surprising that it has found any defenders.

But even as Bremser wrote he and scores of indefatigable workers were accumulating data which were to completely reshape the attitude of the zoological and medical world towards these parasites. In the first place, there was a growing recognition of the fact that the grosser parasites which, from the time of the ancients, had been known to occur in the bodies of man and animals, did not constitute a group absolutely apart, but were animals subject to the same fundamental laws of development as were free-living forms. Thus helminthology, or the study of parasitic worms was recognized as having more than medical interest, and attracted the attention of leading zoologists of the period.

To these workers it was no longer sufficient to explain the occurrence of a tapeworm as due to spontaneous generation from the slime or mucus of the intestine or from the digested food. As early as 1776 Pallas had called attention to the fact that within the little bladders or cysts which occurred within the liver tissue of the mouse there was a jointed worm whose head structures were wholly comparable with those of tapeworms to be found in the intestine of cats. In 1851, the problem was solved by Küchenmeister who proved by experimental feedings that similar bladders from the viscera of rabbits developed into complete tapeworms when fed to dogs. This introduction of the experimental method is justly regarded as the basis of our modern conceptions of the development of internal parasites.

Parallel with and in some important conceptions preceding this discovery of the typical life cycle of a tapeworm was the interpretation of the still more complicated life cycle of the liver fluke. So universally is this form used in class work that we forget the marvel of the story. The steps that led up to its solution are rarely mentioned:

Baker, Adams, and other early microscopists had figured little tadpole-like organisms which they found rarely in pond-water. In 1773, O. F. Muller constituted for these the genus *Cercaria*, which in the light of his times he naturally placed among the Protozoa. It seems to have escaped notice that before 1680 our old entomological friend, Swammerdam had found similar organisms and what we know today as rediæ, in the snail and had figured them.

In his work on the anatomy of "the wonderful viviparous chrystalline snail," as he calls *Paludina*, he tells us that the uterus of the snail "I immediately met under its upper coat which it has in common with the coat of the verge, a congeries of oblong little parts (Fig. vii, a) which were very numerous, and differed somewhat in their length, figure and thickness, and when I removed them from their places, I found they were all alive, and were so many living little worms, as there appeared particles of that sort. On the inside of these worms was seen an oblong transparent ash-gray colored furrow or ridge. When I began to dissect one of these worms, two, nay three, and sometimes four inclosed worms of the same kind issued forth having almost the same figure, that is, a thick head, Fig. viii, a, and *a* small tail *b*, like young frogs or tadpoles." Swammerdam well adds: "I must confess the sight of these astonished me, as I never expected to have met such, and so many miracles in one little creature, or that I should have been so well convinced of my own ignorance and blindness in a single subject."

In 1831 Mehlis made the remarkable discovery that the eggs of certain flukes "contained an embryo which in shape and ciliation resembled an Infusorian; it was occasionally provided with an eyespeck and after being hatched swam about like an Infusorian." (Leuckart.)

The discoveries of Swammerdam, a century and a half before might well have formed a link in the chain, but this link was to be formed anew by Bojanus and by Von Baer. In 1818 Bojanus described brightly colored worms which we now know as rediæ, in pond snails. Von Baer in 1824 showed that these rediæ give rise in their interior to the above-mentioned tailed cercariæ which, becoming free, swim about in the water.

Numerous other workers contributed observations but it remained for Steenstrup to correlate and interpret the data. He pointed out that the embryo escaping from the egg became the free-swimming larva, that this entered the snail and formed a generative sac (the sporocyst) which gave rise to rediæ. From these in turn arise cercariæ which developed into the adult flukes. Remarkable advances in the study of the flukes have been made since 1842, when Steenstrup published his conclusions but the essential facts were made clear by him. It is worth pausing to note that these facts which are fundamental to any control measures against some of the most dangerous of the parasitic worms were obtained through work on forms of no economic importance.

The early workers on insect anatomy occasionally noted the presence of parasitic worms within their specimens. Reference to such are found in Roesel, DeGeer, and Reaumur. The earliest which I have seen is that of Lister who in 1672 not only demolished the view that horse hairs gave rise to snakes, but showed that the so-called "hair-snake" lived for part of its life within "Black-beetles." Von Linstow's epochal studies on the development of Gordius were on a species found in *Pterostichus niger*, possibly this same "black beetle."

As the interest in helminthology grew these scattered references were rapidly multiplied. This is not surprising when we consider the amazing diligence with which the early workers on animal parasites pushed their work. Ten years before his death Bremser wrote that he had with his own hand dissected over 25,000 animals in search for endo-parasites. The collection under his direction, which he was constantly working over, contained specimens from 50,000 hosts.

Rudolphi in 1819 lists 29 species of insects in which had been found nematode worms. Von Linstow 1878, in his Compendium der Helminthologie, lists 220 insect hosts and to these he added 43 species in his "Nachtrag" of 1889.

Some of the most significant of the observations along this line were made by Stein, in the course of his comprehensive work on the female reproductive organs, published in 1847. He found many instances of larval nematodes and cestodes encysted in his specimens.

In a most significant paper, published in 1853, he calls especial attention to these finds and suggests that the larval worms which he found were taken up with their insect host by some other animal in which they reached maturity. His most noteworthy discovery was that in the body cavity of the meal-beetle, *Tenebrio molitor* and its larvæ, there were occasionally to be found numerous microscopic cysts enclosing a tapeworm-like head. These he found in all stages from the recently liberated embryo to the completed cysticercoid, and he suggests that they might be the larvæ of a tapeworm of cats, dogs, rats or mice, or even of man. In the light of our present day knowledge, there is every reason to believe that Stein had found the larval stage of *Hymenolepis diminuta* of rodents and occasionally of man. As we shall see later this tapeworm has as intermediate host a variety of insects, including Tenebrionid beetles.

The first complete life cycle of a parasitic worm involving an insect as intermediate host seems to have been worked out by Leuckart in 1867 for *Protospirura muris* (Spiroptera obtusa), a small, round worm found in the stomach of mice. The eggs of this worm are discharged with the droppings of mice, and are picked up by meal worms and the escaping embryos make their way to the body cavity of the larva and become encapsuled, there to remain until the insect is eaten by a mouse, within which the worm can mature. This case has acquired added significance through recent discoveries that a related worm, developing in the cockroach, is capable of causing cancer of the stomach in rats.

Two years later, in 1869, Leuckart and his student Melnikoff, discovered in the body cavity of the dog louse, cysts which proved to be those of the double-pored tapeworm of dogs, the commonest species infesting these animals. In reality, the worm infestation is more common than is the louse infestation, a fact which was puzzling until 1888, when Grassi found that the dog flea also serves as an intermediate host for the worm. The cysts are so minute that as many as fifty have been found in a single flea. The dog becomes infested solely through swallowing an infested louse or flea. In rare cases this tapeworm is also found as a human parasite, usually in children.

We have seen that Stein early suggested that insects might serve as intermediate hosts for tapeworms of various animals. Of a number of such cases worked out may be cited that of *Hymenolepis diminuta*. This parasite of rodents and occasionally of man is noteworthy for the number and wide range of arthropod hosts in which it may develop. There have been reported the meal-infesting lepidopter *Asopia farinalis*, the Forficulid, *Anisolabis annulipes*, two tenebrionid beetles and three fleas. Recently, there was brought to my attention evidence that the larvæ of this same tapeworm may develop also in myriapods.

An exceedingly common disease in many tropical and subtropical countries is elephantiasis, a disease marked by an enormous swelling of the extremities or affected parts. An apparently isolated endemic center is Charleston, S. C. Typical cases are shown by the lantern slides, the second of which is from a Japanese makimona of the 12th century. Though several conditions may give rise to this disease, it is most commonly due to the presence in the lymphatics of parasitic roundworms, upwards of four inches in length. These discharge living larvæ which are to be found in the blood stream. The life history is especially significant because it is that of the first human parasite found to be dependent upon a mosquito for its development. The larvæ were first noted in 1863, and in 1872 Lewis recognized that the blood of man was their normal habitat and gave to them the name *Filaria sanguinis hominis.* In 1876 Manson discovered the adults and in the following year he and Bancroft simultaneously suggested that they underwent a part of their life cycle in mosquitoes. This fact was very soon demonstrated by Manson, though many of the details have since been worked out.

The larvæ occur in myriads in the blood of the affected individual but are found in the peripheral blood only at night. They are taken up by feeding mosquitoes and within the body muscles of the insect must undergo a development before they are capable of further development in man. In about three weeks they leave the muscles of the mosquito and settle down in its mouthparts, there to await the visit of their host to man. When the mosquito now feeds the larvae are not injected, but escape from the proboscis of the mosquito and actively bore into the skin of their new host, as does the hookworm. In this respect the procedure differs from that of malaria, in which the spores are directly injected by the mosquito.

A related filarial worm *Filaria immitis* lives as adult in the heart of the dog. In this as in the preceding species the larvæ are discharged into the blood and are taken up by mosquitoes. From the stomach of the insect they pass to the excretory or Malpighian tubules, and undergo their metamorphosis there instead of in the muscles. In about two weeks they are ready to enter the dog in the same manner as the preceding.

The guinea worm, *Dracunculus medinensis,* is a filiform parasite of man, upwards of three feet in length, which lives under the epidermis, usually in the leg or foot. Over the vulva of the worm a small hole opens through the epidermis to the surface and through this the microscopic larvæ escape.

The presence of the worm and its products often leads to very severe inflammation, to abscess and sloughing, and even death from secondary infections. The usual method of extraction practiced by natives where the parasite is endemic is to wrap the protruding worm around a stick which is every day given a turn or two until the entire worm is drawn out. The parasite has been known since very remote periods. An illustration in Pigafatta's account of his voyages to the Congo show that this method of extraction was practiced there in 1598. Agitharchides, 150 years B. C., gives an account of the disease as seen on the shores of the Red Sea. It has even been suggested that the fiery serpents which attacked the Israelites in the desert were guinea worms and that Moses set up the serpent on the stick as an illustration of the method of extraction.

As is to be expected, many theories as to the origin of this famous parasite were proposed. Mercurialis, the Italian physician who about 1590 so clearly outlined the theory of the carriage of contagion by flies, ventured again into medical entomology, when he suggested that the guinea worm was contracted from eating grasshoppers. Others believed it identical with the "*Gordius aquaticus*" or hair snake. It was often maintained that infection was conveyed through drinking water and probably many a traveler followed the example of Baron von Jacquin who declared "Well, then, I'm safe enough for I shall not drink a drop of water." We read that in spite of his self-denial he was the only one of his company who became infested.

The prevailing view was that the Guinea worm, lying under the skin instead of in a cavity of the body, afforded conclusive proof of the origin of parasites within the host.

In 1870 Fedschenko first found that if the larvæ discharged by the parent worm escape into water they may be taken up by the little crustacean, *Cyclops* and within its body they develop to a certain stage. Man becomes infested by swallowing the Cyclops in drinking water. Since Fedschenko's announcement there has been abundant verification. We can only conclude that the Baron von Jacquin must have broken his pledge, for we have no evidence that Cyclops will thrive except in water.

Among the worms found to require an arthropod as intermediate host were several species of thorn-headed worms. In 1873 Leuckart showed that *Echinorhynchus proteus* and *Echinorhynchus angustatus* of fish develop as larvæ in two Crustaceans, respectively *Gammarus pulex* and *Asellus aquaticus*. One of this same group of worms which sometimes occurs in man was found by Grassi and Calandruccio, 1888, to develop in the meal infesting larva of Blaps. Still another, the largest of the group, develops in the larva of the June bug.

Other instances might be cited, but it is not my purpose to make this a mere catalogue of the parasites which were early known to undergo a part of their development in insects. It is rather my desire to show that long before the amazing discoveries of the relation of mosquitoes to malaria, and the other contributions of the past twenty-five years, the foundation was being laid. Without that foundation the building could not have been erected. Would it not be interesting if today we could tell what stones are being rejected which may become the cornerstones of the future?

Above all, a review of the history of any theory emphasizes the fact that no man lives to himself alone, and that no honest effort to get at the truths of nature, no matter how insignificant they may seem, is without its value. The man who scorns scientific work which has not an obvious utilitarian trend is ignorant of the history of applied science. The scientific worker who tries to build about himself and his subject a wall of defense against impractical ideas or against what he regards as rival subjects, will merely succeed in insuring himself against recognition by his followers.